

Corporate Performance Efficiency Investigated by Data Envelopment Analysis and Balanced Scorecard

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ABSTRACT

Due to the heightened competition between corporations operating globally, firms have been compelled to utilize various types of performance measurement tools to improve the quality of their products and services. The process of performance measurement can highlight performance fluctuations and provide a sense of direction for performance improvement. In this research study, the performance of Acer Incorporated - a computer manufacturer based in Taiwan - was evaluated and data was from 2001 to 2003 annual report. Because no one performance measurement tool can provide a composite picture of the performance of an organization, the following two performance measurement approaches were used—Data Envelopment Analysis (DEA) and the Balance Scorecard (BSC) Approach. Just as significantly, the findings of this study would help to determine whether the DEA and BSC approaches are informative and effective performance measurement tools. They could thus be applied to other corporations for their performance assessments. It is evident that both the DEA approach and the BSC can offer illuminating information about the performance of a company within a particular sampled period. There is no question that companies would be able to benefit from the information generated from both of these performance measurement methods.

INTRODUCTION

Through the employment of various types of performance measures, corporations can assess the efficiency and effectiveness of their business processes vis-à-vis their strategic objectives. Furthermore, performance measurement tools can help businesses to evaluate their resource allocation process in order to determine how resources can be better managed and distributed to the appropriate channels (Hannula, Kulmala, & Suomala, 1999; The Steering Committee for the Review of Commonwealth/State Service Provision [SCR], 1997; Wright, Smith, Jesser, & Stupeck, 1999). To begin with, in measuring performance, the linkages between the resources used and the outputs generated are clearly established. Identifying the specific relationships between inputs and outputs will enable organizations to determine whether the resources have been allocated appropriately to produce the desired outcomes. Moreover, the quantification of the deficiencies in the performance through the gathering of performance data will enable organizational decision-makers to monitor the organization's performance over time (SCR, 1997).

PROBLEM STATEMENT

Over the last decade, the structure of the computer manufacturing industry has changed dramatically due to the rapid pace of technological innovations. The competitive advantage achieved by the pioneers in the industry as a result of their innovations has been eroded away by the influx of new entrants that have been able to produce low-cost versions. Computer manufacturers have come to recognize the importance of moving their primary focus from Research and Development to other areas of their operations. The challenge confronted by computer manufacturers in the face of the tremendous competition is to be able to provide increased quality in their products and services, while decreasing costs of production (Fanchon, 2003). Even though Acer had generated impressive results during the last three years, its performance was evaluated in greater detail by using the DEA and the BSC approaches.

SIGNIFICANCE OF STUDY

At the level of the individual firm, Acer, the findings derived from the DEA and the BSC approaches could help its decision-makers to assess the company's progress in enhancing the efficiency of its operations during the last three years. From a strategic standpoint, Acer would also be able to determine whether it had been successful in achieving positive financial outcomes based on the analysis of the performance indicators from the four perspectives of the BSC framework. Just as significantly, the findings of this study would also help to determine whether the DEA and BSC approaches are informative and effective performance measurement tools. They could thus be applied to other corporations for their performance assessments.

ASSUMPTIONS

This study was based on the following assumptions: (1) When organizational units achieve technical efficiency, they will improve their organizational performance. (2) The inputs and the outputs selected for the DEA provided an indicator of changes in Acer's technical efficiency over the three-year period. (3) The performance indicators (from the BSC framework) selected for this study provided an accurate indication of Acer's performance and determined how its business processes could be improved to achieve its strategic objectives.

LIMITATIONS

The findings of this study were affected by the following limitations: (1) One of the key limitations of this research study was related to the selection of the appropriate variables for the DEA approach. The DEA model does not provide specific criteria to narrow down the variables that should be used in an analysis. (2) Similarly, the BSC model also has the same limitation with regard to the selection of performance indicators from the four perspectives. Although Kaplan and Norton (1992) briefly mentioned the interrelationships between the perspectives in their work, they did not offer specific examples of their relationships. (3) Apart from the limitations associated with the two approaches, this research study was further limited by the narrow selection of inputs and outputs, as well as performance indicators (one from each perspective).

LITERATURE REVIEW

Data Envelopment Analysis

The primary purpose of DEA is to compute the technical efficiency of organizational units. In measuring technical efficiency, the transformation of inputs such as employee services and raw materials into outputs is compared to best practice organizational units. Essentially, 100 percent technical efficiency is achieved when "no wastage of inputs" has occurred in generating the specific amount of output. For organizational units that are operating below the best practice levels, their level of efficiency is represented as a percentage of the best practice organizational units (SCR, 1997). One of the primary strengths of the DEA approach rests on its relative simplicity in requiring simply the output and input quantities to compute technical efficiency, without needing to include the prices. In addition, the DEA approach generates data that identify possible causes of inefficiency based on the computation of efficiency levels. Finally, the DEA approach pinpoints organizational units that have proven to be efficient in their utilization of inputs. Thus, inefficient units will have role models that can guide them in learning how they can improve the implementation of their operations (SCR, 1997). Since the data of each organizational unit are given equal weight in a DEA approach, the shape of the efficiency frontier can be distorted with the inclusion of the organizational unit. Therefore, in putting together the data, it is vital to exclude data whose output-to-input ratios exceed the sample mean by 2.5 standard deviations (SCR, 1997). Moreover, the measurement of efficiency in a DEA approach is solely confined to the comparison of the organizational units within the sample. Essentially, its findings cannot be used to compare with those of other studies or generalized to include other types of populations (SCR, 1997). Finally, the DEA approach is highly dependent on the number of inputs and outputs, as well as the sample size.

Previous Study: Application of DEA to a Public Accounting Firm

The particular research study has been chosen for discussion because a similar approach was used for the analysis of Acer as a single organizational unit for the DEA. Banker et al. (2002) sought to measure the productivity in order to determine whether the implementation of information technology at the firm in 1998 exerted an impact on the company's performance. Based on the quantitative data that yielded different efficiency ratings for the 24 months during the study period, Banker et al. (2002) concluded that the introduction of information technology in 1998 led to an increase in productivity for the firm from 1997 to 1999 (see Table 1). The findings of this study demonstrated the applicability of the DEA approach to the measurement of a firm's productivity at different points in time.

Table 1 Estimated DEA Inefficiency

Year	Mean Inefficiency	Standard Deviation
1997	1.0851	0.1152
1999	1.0510	0.0618

Adapted from "Impact of Information Technology on Public Accounting Firm Productivity," by R. D. Banker, H. H. Chang, and Y. C. Kao, 2002, *Journal of Information Systems*, 16(2), p. 220.

Conceptual Framework of the BSC

Developed by Kaplan and Norton (1992, 1996), the BSC approach can be used to connect a company's strategic objectives to their performance measurements in the following ways. First, it identifies specific measurements that are useful in leading firms to the development of their strategic objectives. Second, it brings together the measures that constitute the chief determinants of the firms' overall performance. Finally, the BSC approach focuses on specific business processes that can yield beneficial outcomes for the firms. Using this strategic management tool that incorporates both financial and non-financial measures, managers can gather information about their organizations' ongoing efforts to integrate their vision and strategies with their organizational performance, by using specific metrics (Kaplan & Norton, 1992, 1993; Missroon, 1999). They are categorized under the following categories: financial, customer satisfaction, business processes, and learning and growth (Wright et al., 1999). For the purposes of this study, only specific quantifiable performance indicators were selected so that further analysis could be conducted by using a regression model. The basic BSC framework encompasses both quantitative and qualitative measures to determine the performance or organizations.

Application of the BSC Analysis to Compaq

Wright et al.'s (1999) analysis of Compaq's business re-engineering efforts will be presented and discussed: (1) *Financial perspective*: The financial success of Compaq in 1997 was determined by several measures in this category: (a) Compaq increased its net sales from \$4 billion in 1992 to \$24 billion in 1997. (b) During the same five-year period, Compaq's revenue growth rate was maintained at 31 percent. (c) The yearly net income also rose from \$213 million in 1992 to \$1.8 billion in 1997 (Wright et al., 1999). (2) *Customer perspective*: The measure that captured customer perceptions of Compaq was market share. This measure reflected the customers' perceptions of the company's pricing of the products and their endorsement of the quality of the product, given the prices. In this regard, Compaq also performed outstandingly in 1997, with an increase in market share from 9.3 percent of the U.S. market to the 18.1 percent in 1997 (Wright et al., 1999). (3) *Internal processes perspective*: Compaq's chief concern in this area was the reduction of the time required for the company to respond to the changes in the customers' preferences and deliver innovative products efficiently. Based on this objective, one of the primary measures in this perspective is the market share captured by Compaq with regard to a specific product. (4) *Learning and growth perspective*: Compaq was focused on building partnerships and alliances with other industry leaders and value-added resellers, compensating for Compaq's lack of capacity to develop innovative products (Wright et al., 1999). Thus, in this perspective, revenue generated by the alliances forged with other companies could be used as a quantitative measure of this perspective. However, Wright et al. (1999) did not seek to quantify this perspective in their discussion.

RESEARCH METHODOLOGY

Research Design and Data Collection

The data used for this analysis were gathered from Acer's annual reports from 2001 and 2003. It is important to point out that the two inputs selected for the DEA approach were differentiated by the fact that cost of revenues deal with costs of production, while operating expenses consist of selling, administrative, as well as research and development expenditures. The data that were utilized for the DEA approach are presented in Table 2.

Table 2 Inputs and Output of Acer, 2001-2003

	2001 (NT\$ '000s)	2002 (NT\$ '000s)	2003 (NT\$ '000s)
Revenue (Output)	93,022,422	107,350,848	157,655,398
Cost of Revenues (Input 1)	83,649,775	92,720,031	136,525,463
Operating Expenses (Input 2)	12,831,289	14,452,948	18,970,743

Adapted from Acer, 2002 Annual Report, 2002, retrieved November 29, 2004, from

[http://global.acer.com/about/investor/pdf/AI%202002%20Annual%20Report%20\(E\).pdf](http://global.acer.com/about/investor/pdf/AI%202002%20Annual%20Report%20(E).pdf);

Acer, 2004, 2003 Annual Report, retrieved November 29, 2004, from <http://global.acer.com/about/pdf/Y2003AnnualReportEnglish.pdf>

The data for the performance indicators from each of the four perspectives in the BSC framework, which were analyzed, are also provided below (Table 3).

Table 3 Acer's Performance based on Selected Performance Indicators, 2001-2003

Year	Financial: Revenue (NT\$ '000s)	Customer: Net Sales to Key Buyers (NT\$ '000s)	Business Process: Inventory Turnover (Number of times)	Learning and Growth: R & D (NT\$ '000s)
2001	93,022,422	18,459,271	14.83	88,927 (48% of total expenditure)
2002	107,350,848	42,137,284	20.73	88,257 (21% of total expenditure)
2003	157,655,398	81,717,814	49.43	282,602 (35% of total expenditure)

Adapted from Acer, 2002 Annual Report, 2002, retrieved November 29, 2004, from

[http://global.acer.com/about/investor/pdf/AI%202002%20Annual%20Report%20\(E\).pdf](http://global.acer.com/about/investor/pdf/AI%202002%20Annual%20Report%20(E).pdf);

Acer, 2004, 2003 Annual Report, retrieved November 29, 2004, from <http://global.acer.com/about/pdf/Y2003AnnualReportEnglish.pdf>

Validity and Reliability

According to Fanchon's (2003) analysis, the most relevant inputs that should be included in the analysis of the technical efficiency of computer companies are costs of goods for production, research and development expenditure and advertising expenses. Similarly, for this research study, the inputs used in the DEA analysis were also similar to these variables: cost of revenues and operating expenses (that include research and development, along with advertising expenses). Moreover, the weaknesses of each of the performance assessment tools – the DEA and the BSC – were also compensated by the utilization of both of these approaches, thus providing for triangulation. Therefore, the replication of the findings or the assessments could determine whether the findings were reliable. Conversely, conflicting results would illuminate the need to re-examine the variables selected for these analyses. Finally, the emphasis of this research study was to assess the viability of the DEA and the BSC approaches as effective performance assessment tools, rather than to provide a comprehensive assessment of Acer's performance.

RESULTS

DEA Approach

The first step in this analysis was to calculate two ratios for each of the three years. The first ratio is revenue divided by the cost of revenues as appeared below in Table 4. Results from this analysis indicate that the ratio was lowest in 2001, thus suggesting that Acer might have been the least efficient that out year of the three years sampled. In 2002, the ratio increased to 1.16, and then in 2003, it decreased slightly to 1.15. The second set of ratios calculated was for revenue divided by operating expenses as appeared below in Table 5.

Table 4 Ratio of Revenue / Cost of Revenues

Case Summaries ^a				
				Cost ratio
YEAR	2001.00	1		1.11
		Total	N	1
	2002.00	1		1.16
		Total	N	1
	2003.00	1		1.15
		Total	N	1
Total		N		3

a. Limited to first 100 cases.

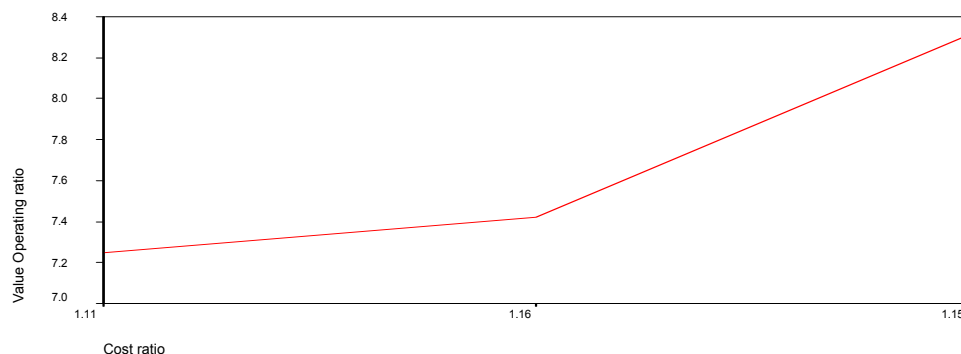
Table 5 Ratio of Revenue / Operating Expenses

Case Summaries ^a				
				Operating ratio
YEAR	2001.00	1		7.25
		Total	N	1
	2002.00	1		7.42
		Total	N	1
	2003.00	1		8.31
		Total	N	1
Total		N		3

a. Limited to first 100 cases.

Results indicated that the ratio of revenue to operating expenses had gradually increased from 2001 to 2003. Specifically, the ratio was 7.25 in 2001, but by 2003, it had risen to 8.31. This ratio indicated that Acer had been successful in increasing each unit of revenue relative to each unit of operating expenses over the sampled three-year period. The second step in this analysis was to graph the ratios by year to highlight the most inefficient and efficient years. Results appear below in Figure 1.

Figure 1. Ratios by year



BSC Framework Results

The four frequency distribution tables for performance indicators were as follows:

Table 6 Frequency Distribution of Revenue

REVENUE					
	Frequency	Percent	Valid Percent	Cumulative Percent	
Valid 93022422.00	1	33.3	33.3	33.3	
107350848.00	1	33.3	33.3	66.7	
157655398.00	1	33.3	33.3	100.0	
Total	3	100.0	100.0		

Table 7 Frequency Distribution of Net Sales

Net Sales					
	Frequency	Percent	Valid Percent	Cumulative Percent	
Valid 18459271.00	1	33.3	33.3	33.3	
42137284.00	1	33.3	33.3	66.7	
81717814.00	1	33.3	33.3	100.0	
Total	3	100.0	100.0		

Table 8 Frequency Distribution for Business Process

Business Process					
	Frequency	Percent	Valid Percent	Cumulative Percent	
Valid 14.83	1	33.3	33.3	33.3	
20.73	1	33.3	33.3	66.7	
49.43	1	33.3	33.3	100.0	
Total	3	100.0	100.0		

Table 9 Frequency Distribution of R&D

Research and development					
	Frequency	Percent	Valid Percent	Cumulative Percent	
Valid 88257.00	1	33.3	33.3	33.3	
88927.00	1	33.3	33.3	66.7	
282602.00	1	33.3	33.3	100.0	
Total	3	100.0	100.0		

Results from the correlational analysis appear below in Table 10. Pearson's product moment correlation was used given that all the variables are measured on interval scales. Total financial revenue was used as the dependent variable, as this is the variable we would like to be able to predict.

Table 10 Correlation Results

Correlations					
		REVENUE	Net Sales	Business Process	Research and development
REVENUE	Pearson Correlation	1	.986	.999*	.977
	Sig. (2-tailed)	.	.106	.033	.137
	N	3	3	3	3
Net Sales	Pearson Correlation	.986	1	.976	.928
	Sig. (2-tailed)	.106	.	.140	.243
	N	3	3	3	3
Business Process	Pearson Correlation	.999*	.976	1	.987
	Sig. (2-tailed)	.033	.140	.	.104
	N	3	3	3	3
Research and development	Pearson Correlation	.977	.928	.987	1
	Sig. (2-tailed)	.137	.243	.104	.
	N	3	3	3	3

*. Correlation is significant at the 0.05 level (2-tailed).

Correlational results indicated near perfect linear relationship among several of the variables. For example, there was a strong and positive correlation between research and development and revenue ($r = 0.977$). However, because of the sample size, the relationship was not significant. There was also a very close to perfect correlation between business process and revenue ($r = 0.999$; $p < 0.05$) that was significant and would be much stronger if the sample size were to increase. A strong and positive relationship was found between net sales and revenue ($r = 0.986$), but again due to sample size, the relationship was not significant. Relationships among the other variables also indicated near perfect linear relationships. For example, there was a strong and positive relationship between research and development and net sales ($r = 0.928$), as well as between research and development and business process ($r = 0.987$). Unfortunately, none of these relationships was significant due to low sample sizes. Given the strong, almost perfect linear relationship between these variables, regression analysis is not appropriate and will not tell us anymore than the correlational analysis did. However, a regression model was run and results appear below in

Table 11. Results from the regression clearly illustrate the futility of such analysis when variables were so strongly correlated with each other. Changing the dependent variable to one of the other three also did not resolve this issue.

Table 11 Regression Results

ANOVA ^b						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.30442E+15	2	1.152E+15		
	Residual	.000	0			
	Total	2.30442E+15	2			

^a. Predictors: (Constant), Research and development, Net Sales

^b. Dependent Variable: REVENUE

CONCLUSION

In spite of some limitations, the findings of this study still have significant implications for Acer. Perhaps most importantly, the findings produced by the DEA approach offered an affirmation of Acer's business strategy in 2003. As noted in its *2003 Annual Report*, Acer had succeeded in increasing its revenues while lowering its relative costs, by establishing a more cost-effective supply chain that involves the participation of quality vendors and partners at different points of the supply chain. Consequently, Acer had been able to create value-added products without increasing its own costs substantially. Furthermore, it had also engaged in an active effort to lower its inventory level, thus allowing it to reduce overhead costs and increase operational efficiency (Acer, 2004).

As for the BSC analysis, the identification of the strong and positive correlations between the performance indicators was highly important in illuminating the specific areas of focus for Acer in the forthcoming years. One of the most important findings in the BSC analysis was the importance of research and development in virtually all key aspects of Acer's performance. The performance indicator of the amount of expenditure devoted to research and development had a strong and positive correlation with revenue, net sales to key buyers and the extent of inventory turnover, in terms of the number of times a year. These findings thus strongly suggested that Acer should continue to invest the firm's capital resources in research and development. Even though it is outsourcing some of its research and development operations to various vendors in order to benefit from the latter's expertise and knowledge (Acer, 2004), the findings indicated that Acer should not slacken in their own efforts to invest in the development of new products. Reviewing the spending trends with regard to research and development, it was evident that Acer had briefly decreased its emphasis on research and development in 2002, when its expenditure in this area dropped to 21 percent of the total expenditure, compared to the previous year (48 percent). This move was undoubtedly in response to the downturn in the global high-tech markets in 2001. Nonetheless, Acer appeared to have recognized the need to continue to place a strong emphasis on research and development by increasing the relative amount allocated to this area. The research and development expenditure constituted 35 percent of the total expenditure in 2003 (Acer, 2004). Just as significantly, the findings also demonstrated a significant, virtually perfect and positive correlation between inventory turnover, in terms of the number of times each year, and revenue. Essentially, how quickly Acer had been in selling its products, which was related to the efficiency of its marketing efforts, exerted a significant impact on the revenue generated.

Even though research and development that leads to the production of new products is clearly important in the case of a computer company, the IT industry, as recognized by Acer, has also reached saturation levels (Acer, 2004). In other words, the supply of computer products far exceeds the demand. Therefore, the positive correlation between inventory turnover and revenue thus showed that how Acer is able to market and provide a full range of products and services will determine whether it will be able to produce increased revenue in the future. Already, Acer has begun to acknowledge the importance of the marketing aspect of the company's operations. Instead of focusing solely on its manufacturing operations, Acer has sought to market itself as a provider of "a global brand of products and services" (Acer, 2004, p. 38). In plainer English, apart from developing advanced IT products, Acer has also attempted to enhance its ability to integrate information technology into customers' business operations. As a result, it has branched into a wide variety of areas such as selling peripheral products that support the operations of computers; providing computer repair and maintenance services; and customizing products and services to meet the specific needs of the customers (Acer, 2004).

RECOMMENDATIONS

DEA Approach

In utilizing the DEA approach, managers should be aware of the types of questions that can be addressed by this particularly performance measurement approach. According to Fried and Lovell (1994), the following questions can be addressed by the DEA approach (SCR, 1997): (1) How should managers identify the most appropriate organizations to use as potential benchmarks? (2) Which aspects of the organization are considered the most efficient? (3) What type of input and output combinations should be used to ensure that the organization is performing at the highest efficiency level? (4) What are the

specific characteristics of efficient operating facilities and how do they apply to the targeted organization? (5) What is the optimum scale for the size of an organization's operation? What is the impact on the costs of operations by reaching the optimal size? (6) To what extent do the differences in the external circumstances affect the relevance of the results pertaining to the relative performance of the different organizations? To take into account differences in operating environments when comparing between different organizations, or even the same organization at different time periods, more factors should be included into the analysis. The purpose of these factors is to achieve a comparison between the organizations, which eliminate the differences in the external environments. To address this, Nunamaker (1985) offered a rule of thumb: "the number of organizations in the sample should be at least three times greater than the sum of the number of outputs and inputs included in the specification" (in SCR, 1997, p. 23).

BSC Analysis

What the strong and positive correlations of the different performance indicators from the four perspectives reveal is the need to acknowledge the linkages of the indicators. Instead of considering each of these performance indicators or the different perspectives as isolated variables, companies need to take into consideration their linkages. Essentially, changes in one of the performance indicators can have significant ramifications for the others. For instance, in the case of Acer, the rate of the inventory turnover had a virtually perfect positive correlation with revenue, thus heightening the significance of the marketing effort in determining financial performance. Similarly, in the case of Compaq, the improvements in the business operation processes such as improving the quality of the supply chain also led to improved customer results such as the expansion of markets (Wright et al., 1999). The synergistic combination of all the performance indicators thus needs to be recognized because it will ultimately determine the level of success of the companies (Wright et al., 1999).

Ultimately, in utilizing either or both of these performance measurement methods, it is vital for companies to predetermine their objectives in order to select the appropriate indicators. In addition, companies should also be aware of the strengths and weaknesses of both of these performance measurements methods. For example, the DEA approach is largely a comparison approach involving selected sample organizations. The accuracy of the measurement of the efficiency levels is also dependent on the selection of appropriate variables. Similarly, the BSC analysis will most likely generate the best results when the relevant performance indicators are selected and the interrelationship among them identified. In spite of the aforementioned concerns, the case study analysis in this study has shown that even in the most simplified form, the two performance measurement methods can offer helpful perspectives of a company's performance. In fact, the interpretation of these findings translated into business strategies that were already being pursued by Acer. Therefore, by adhering to the above recommendations pertaining to the DEA approach and the BSC analysis, there is no question that companies would be able to benefit from the information generated from both of these performance measurement methods.

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